USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Project ID: 2005PA43B

Title: A Bayesian Framework for Cost Effective Groundwater Monitoring Design

Project Type: Research

Focus Categories: Groundwater, Models, Solute Transport

Keywords: groundwater monitoring, optimization, genetic algorithm, decision support

Start Date: 03/01/2005

End Date: 02/28/2006

Federal Funds: $18,000

Non-Federal Matching Funds: $36,000

Congressional District: 5th

Principal Investigator:
Patrick M. Reed

Abstract

The goal of this proposed research is to develop the Adaptive Strategies for Sampling In Space and Time (ASSIST) decision support framework for designing cost-effective long-term groundwater monitoring (LTM) networks. The ASSIST monitoring framework will provide the first adaptive observation system design paradigm that will enhance hydrologic scientists' abilities to (1) balance multiple design objectives while characterizing complex groundwater systems across space-and-time, (2) merge physical model predictions with a broad range of data sources (e.g., indicator contaminant samples, expert knowledge, real-time data series), (3) consider a much broader range of model and data uncertainties, and (4) adapt their objectives and system design to account for advances in real-time sensing. The objectives of this research are to:

1. Develop the ASSIST methodology to support the cost-effective design of long-term groundwater monitoring networks.

2. Apply the methodology at the Shale Hills experimental watershed located in north central PA within the Valley and Ridge Province of the Susquehanna River Basin. The ASSIST monitoring framework will couple the ability of the Nondominated Sorted Genetic Algorithm-II (NSGA-II) to perform multiobjective optimization with the

advanced spatiotemporal visualization and uncertainty modeling capabilities of the Bayesian Maximum Entropy (BME) library. Optimizing systems for multiple objectives often leads to tradeoff or “Pareto optimal” solutions that can be used for cost-benefit analysis.

The ASSIST framework’s monitoring design capabilities will be tested at the Shale Hills experimental watershed. The test case will be used to carefully validate the ASSIST monitoring framework’s effectiveness relative to current design methods and justify broad dissemination of its software tools. The Shale Hills 19.8 acre experimental watershed was established in the 1970’s by the Forest Hydrology group at Penn State to experimentally determine the physical mechanisms of streamflow generation for an upland forested catchment and to evaluate the effects of antecedent soil moisture on storm flow volume and timing. Historical and current research at the site will provide the opportunity to demonstrate our methodology for the two scenarios discussed below:

Scenario 1: An extensive monitoring network exists and the ASSIST framework will be used to analyze the value of existing and proposed monitoring stations in reducing site uncertainties.

Scenario 2: Given fixed funds and a new experimental site, the ASSIST framework will be used to identify the locations, sampling rates, and observation technologies for new monitoring stations. Note this will be part of a long-term research effort that extends beyond the time frame of this proposal.

The expected outcome of this proposed research will be a new monitoring design framework that will enhance our ability to cost-effectively characterize the quantity, quality, and susceptibility of groundwater resources within Pennsylvania and throughout the United States. The multiobjective decision support tools will provide stakeholders and policy makers with a better understanding of the value of adding monitoring points into existing networks and allow them to exploit a broader array of information sources. This project is expected to generate the following deliverables: (1) ASSIST Monitoring Software Library, (2) Journal Publications, and (3) Conference Publications. The ASSIST tools will be developed to maximize their general applicability across scientific disciplines, ensuring that they can be used to optimize large-scale investments into a broad array of environmental observation systems (e.g., the CLEANER, CUAHSI, or NEON initiatives).